TUTORIALS

Evaluating a Picture Archiving and Communications System Workstation

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An efficient environment for picture archiving and communications systems (PACS) in the radiology department and throughout a medical practice requires good hardware, good software, and integration of the information sources that exist in a radiology department and institution. This tutorial will describe some of the considerations in evaluating a PACS workstation, with a view to the hardware requirements, user interface designs, and integration with the information systems.

WORKSTATION HARDWARE CONSIDERATIONS

THE NEED FOR good hardware is obvious—you need to be able to display images quickly and the images must be displayed with high quality. This evaluation would seem to be fairly straightforward and indeed is the easiest part of the picture archiving and communications system (PACS) workstation evaluation process. The evaluation of the hardware of a PACS workstation include the actual computing unit, the monitor, and the network interface.

The central processing unit (CPU) controls the transfer of data. It may also perform manipulations of the image such as spatial filtering, but window width and level settings or zooming and panning are typically performed by dedicated processors on the display card. Therefore, while a faster CPU is generally better, it does not deserve detailed scrutiny. The amount of random access memory (RAM) for the CPU and the display card will generally have much more impact on how well the system performs.

The display has a significant impact on image quality. The American College of Radiology (ACR) has specified several measurements that it recommends for image interpretation, including spatial resolution ($\geq$2.5 lp/mm), contrast resolution ($\geq$8 bits/pixel), and brightness ($\geq$50 ft-L).[1] A 2.5K $\times$ 2K pixel resolution is probably necessary for efficiency reasons if radiographs are to be interpreted, with somewhat lower resolution demands for cross-sectional interpretation. Until recently, only cathode-ray tubes (CRTs) could display these high resolution images. However, semiconductor-based flat panel displays are becoming available that can display 2.5K $\times$ 2K pixels with costs projected to be approximately twice that of CRTs. Flat panels are expected to have longer lives and greater stability than CRTs, and may justify the higher initial cost. Color can be used effectively to increase the usability of PACS displays, but is difficult/expensive to implement in high-resolution CRTs. Flat panels may more easily support color at high resolution.

There are several competing network technologies; all serve to communicate information between computers. In the early days of PACS, standard commercial network technology was not able to transmit images at the rate that the user would like to view them. Therefore, the PACS used rules to transfer images to a workstation prior to radiologist viewing. In this case, the speed of the network is not important and instead the demand is placed upon the local hard disk(s). An important assumption was that the workstation where images will be viewed could be predicted. Other systems used a central store of images, with a proprietary network that could transfer images at display rates.

Increased performance of commercial network technology has lessened the need to predict (or "autoroute"). Whereas 10 Mbit/s transfer speed was the standard, 100 Mbit/s is now quite common, and 1,000 Mbit/s and more is becoming available for desktop personal computers. This reduces the transfer time for a standard computed radiology (CR) image from about 10 seconds to 1 second (or 0.1 second for the fastest).

Finally, the reliability and redundancy of the

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hardware must be evaluated, as well as how the configuration supports operation when components have failed, and how recovery can be achieved. This is a complex task. Contacting other customers can help to assess the reliability of components. Understanding how failures have affected their departments is also extremely helpful, as is information about how the vendor responded. Hardware maintenance, reliability specifications, and provisions for upgrades cannot be overlooked when negotiating the purchase. Remember that 99% up-time means that the system can be nonfunctional for 7.4 hours per month!

SOFT-COPY INTERPRETATION TOOLS

Although viewing computed tomography (CT) scans and radiographs may be similar when using films and a light box, viewing the images soft copy seems to be substantially different. One important difference is that cross-sectional images can be three dimensional, which may provide additional information if viewed as a "stack." CT images have presets for certain components of the image such as soft tissues, bones, or lungs. CTs and magnetic resonance images (MRIs) also have a smaller image matrix, allowing many more images to be displayed for a certain number of pixels on the monitor. CTs and MRs also have multiple series of images per examination, whereas radiographs usually have only a few images per examination.

For CR, there are six or seven "reading tools" that are considered to be important for diagnostic reading. These include the ability to easily rearrange images, adjust window width and level, magnify and zoom, flip and rotate, invert gray scale, measure distances, angles, and areas, and annotate the image. This contrasts with needs in cross-sectional to view images in stack, page, and cine formats, with presets for CT and automatic width and level calculations for MR, with the ability to adjust these widths and level values, measure pixel values, distances and areas, annotate and perhaps image flip and rotate. More complex computations like multiplanar reformats (MPRs) and maximum-intensity projections (MIPs) can also be useful, and require greater CPU speed.

For any soft-copy reading package, there should be a single image display metaphor (IDM). An IDM is the underlying concept of how the software designer expects the user to interact with images. It is clearly advantageous for the IDM to be easy to understand or remember and it should be generalizable/powerful. If it is, users can predict how to accomplish a function or arrangement which they had not been taught or cannot remember. In evaluating a PACS workstation you should try to determine what that metaphor is and decide whether or not the IDM is comprehensible, reasonable, consistently followed for all types of images, and whether or not that metaphor is powerful.

There are probably three generations of IDMs that have been used. The first generation was easy to understand but not very powerful because it basically allowed for one image on the screen. Adjusting width and level or a next or previous image applied to that one image.

In the second generation IDM, windows debuted, and each window displayed an independent set of images. This allowed simultaneous display of multiple images, and is similar to a multifilm light box. This model is also easy to understand but still not very powerful.

Vendors are now starting to implement what I consider to be a third generation: image areas. Image areas can communicate with other image areas and are basically portions of the display screen for one or more images to be displayed. The difference from an window is that it has intelligent behavior which is based on image type and the fact that it can communicate between itself and other image areas. An example of this would be pulling up a new and old examination in two image areas. Once these have been properly aligned, you should be able to click "next" and have both image areas advance.

In a second generation IDM more monitors is advantageous. It is possible that as third generation interfaces improve that one would want to reduce the number of monitors as the interface makes it more efficient for the computer to move images to the monitor you are focusing on rather than for you to focus your eyes on to a different monitor. Either four or two displays is likely to be the optimal number.

I believe there may be room for a further improvement by the integration of specialized keyboards or keypads which allow a more natural interaction for the common things radiologists need to do such as adjust window level or do next previous. While it is certainly possible to accomplish this with a mouse or a keystroke, a dedicated keypad could probably be more efficient and easier for the novice user. The most common operations for image interpretation are "Next," "Previous," window width and level adjustments, and pan/zoom. These operations must be single step operations to be efficient.

INFORMATION SYSTEM INTEGRATION

It would be hard to underestimate the importance of integrating image information with textual information such as that stored in a typical radiology information system (RIS). The RIS provides practical information (required by the ACR[1]) such as the age and sex of the patient, as well as (hopefully) the indication for examination and the referring physician. Perhaps even more crucial is the integration of RIS with PACS to create a worklist. In a production environment it is not feasible for a radiologist to select the next patient from the list of all possible patients on a PACS. Rather, a worklist is the list of all examinations that are to be read, perhaps filtered by some criteria such as the anatomy and/or the modality. After an examination is reported, the radiologist can click a button to get the next examination from the worklist. Without the integration of order information from the RIS and the PACS, a worklist is impossible.

The worklist also allows prediction as to which images are likely to be required on a certain workstation and can potentially reduce the network requirements. The ability to rapidly bring up the next case has a significant impact on the productivity of the radiologist. A global worklist allows gains in system wide efficiency of the radiology department because it allows them to read images located anywhere at the time which is most convenient. This means, of course, that the system must prevent contention between radiologists that might attempt to interpret the same examination. Other advantages of system integration is that as soon as a radiologic exam is ordered, the RIS can instruct the PACS to retrieve any previous examinations allowing maximum opportunity for comparison with prior examinations (prefetching).

CONCLUSION

A successful PACS implementation requires well designed hardware, a thoughtful software implementation, and a high degree of integration of PACS and RIS information. While it may be difficult to avoid some of the technical jargon, perhaps the most important evaluation step is to sit at a workstation and see if the image display metaphor one that can conform to your image interpretation style. Finally, integration of RIS and PACS is crucial.

REFERENCE

1. American College of Radiology: Standards 1998. Reston, VA, ACR, 1998, pp 3-11